AMENDMENTS TO THE SPECIFICATION

IN PAGE 1

IN THE PARAGRAPH BEGINNING AT LINE 12 WITH THE WORDS "The present invention relates ..." AND ENDING WITH THE WORDS "...such as polymethylmethacrylate ("PMMA")." PLEASE AMEND THE SPECIFICATION WITH THE REPLACEMENT PARAGRAPH AS FOLLOWS:

The present invention relates to a method for quickly providing silicon micro-molds for the fabrication of mechanical micro-components, particularly mold having very high aspect ratios wherein the mold has lateral feature dimensions on the order of microns while also having depth dimensions on the order of hundreds of microns. Furthermore, the present invention provides a silicon mold that does not change dimension or distort due to water absorption ~~and/or during~~ and/or due to thermal cycling, as do prior art mold materials such as polymethylmethacrylate ("PMMA").

IN PAGE 2

IN THE PARAGRAPH BEGINNING AT LINE 3 WITH THE WORDS "Current methods for fabricating.." AND ENDING WITH THE WORDS "..those skill in the art." PLEASE AMEND THE SPECIFICATION WITH THE REPLACEMENT PARAGRAPH AS FOLLOWS:

Current methods for fabricating molds for LIGA micro-component rely on high fluence, high brightness x-ray sources, typically synchrotron generated x-rays that are carefully collimated and directed onto a pattern-forming lithographic mask that replicates the image of the mask pattern into a layer of polymethylmethacrylate (PMMA). X-rays falling onto the surface of the PMMA substrate disrupt the molecular bonding in the exposed region and render it sensitive to chemical attack. Thus, by carefully controlling the amount and spatial location of the x-ray radiation, very small and very detailed features can be reproduced in the PMMA substrate This process, however, is slow and limited by the availability of the synchrotron sources having the necessary fluence to deeply penetrate the PMMA substrates used by those ~~skill~~ skilled in the art.

IN THE PARAGRAPH BEGINNING AT LINE 15 WITH THE WORDS "U.S. Patent serial number.." AND ENDING WITH THE WORDS "..for directional etching." PLEASE AMEND THE SPECIFICATION WITH THE REPLACEMENT PARAGRAPH AS FOLLOWS:

U.S. Patent serial number *5,501,893* to Laermer, et al. describes a lithographic technique for etching silicon, generally referred to as "anisotropic etching," where it is possible to achieve ~~deeply-extending~~ deeply extending trenches while simultaneously providing side walls which are as nearly parallel and vertical as desired. In order to achieve these geometries it is necessary to allow etching to progress only on the bottom of the etched trench in the silicon substrate and not on the walls of the trench. In particular, Laermer (*'893*) teaches a ~~two-stage~~ two-stage process for alternately etching an exposed silicon surface in a reactive ion plasma followed by coating the etched surfaces with a thin polymerized layer, wherein the polymer coating serves to protect the wall surfaces of the trench from action of the plasma since these surfaces do not directly face the incoming flux of plasma ions. However, the polymer layer applied to the "floor" surface of the trench quickly breaks down in the presence of the ion bombardment since this surface directly faces the incoming ions. The polymer layer, therefore, forms a very effective etching "stop" on those edges or surfaces not directly in the path of the ion flux allowing for directional etching.

IN PAGE 3

IN THE PARAGRAPH BEGINNING AT LINE 6 WITH THE WORDS "The inventors have.." AND ENDING WITH THE WORDS "..micro-component parts." PLEASE AMEND THE SPECIFICATION WITH THE REPLACEMENT PARAGRAPH AS FOLLOWS:

The inventors have realized that such a process can be used to create template structures out of silicon wherein the template structures comprise the inverse 3-dimensional image of the desired micro-components. The etched silicon wafer can therefore be used as a plating micro-mold into which a metal can be deposited, thereby forming the useful micro-component parts.

IN PAGE 4

IN THE PARAGRAPH BEGINNING AT LINE 17 WITH THE WORDS "FIGURE **1F** illustrates.." AND ENDING WITH THE WORDS "..silicon micro-mold." PLEASE AMEND THE SPECIFICATION WITH THE REPLACEMENT PARAGRAPH AS FOLLOWS:

FIGURE **1F** illustrates the silicon substrate after the exposed portions of the substrate ~~has~~ have been subjected to an etching plasma and etched through the thickness of the silicon wafer until the opposite side metal layer has been reached, thereby forming the silicon micro-mold.

IN THE PARAGRAPH BEGINNING AT LINE 24 WITH THE WORDS "FIGURE **2B** shows.." AND ENDING WITH THE WORDS "..SiO_2 release layer." PLEASE AMEND THE SPECIFICATION WITH THE REPLACEMENT PARAGRAPH AS FOLLOWS:

FIGURE **2B** shows the silicon substrate after the wall surfaces of the silicon micro-mold have been oxidized to form a SiO_2 release layer.

IN PAGE 5

IN THE PARAGRAPH BEGINNING AT LINE 7 WITH THE WORDS "The present invention provides.." AND ENDING WITH THE WORDS "..greater than 1 micron." PLEASE AMEND THE SPECIFICATION WITH THE REPLACEMENT PARAGRAPH AS FOLLOWS:

The present invention provides a process for rapidly fabricating a robust 3-dimensional silicon micro-mold for use in preparing complex metal micro-components. The present invention also provides a silicon mold capable of replicating structural elements exhibiting features having lateral dimensions of 1 micron or less. Such molds have great utility for producing metal and ceramic microparts since current technology ~~provide~~ provides molds having lateral ~~features~~ feature sizes greater than 1 micron.

IN THE PARAGRAPH BEGINNING AT LINE 14 WITH THE WORDS "The instant invention employs.." AND ENDING WITH THE WORDS "..the finished micro-component." PLEASE AMEND THE SPECIFICATION WITH THE REPLACEMENT PARAGRAPH AS FOLLOWS:

The instant invention employs a combination of processes to provide micro-molds which ~~overcomes~~ overcome these limitations. A lithographic mask is used to replicate the desired mold wall geometry into a layer of photoresist applied to ~~a~~ an industry standard silicon wafer. The resist is then exposed to a source of high intensity light, developed to remove the undesired portion of the resist layer, and etched using a reactive plasma to provide a series of deep trenches through the thickness of the silicon wafer in the areas exposed by the resist removal, thereby providing the silicon micro-mold. Micro-component parts are prepared using the micro-mold by plating, or otherwise applying a metal deposit into the trenches in order to completely fill the trenches with the metal deposit. The surfaces of the plated micro-mold are subsequently planarized, and the underlying silicon substrate chemically removed to provide the finished micro-component.

IN PAGE 6

IN THE PARAGRAPH BEGINNING AT LINE 5 WITH THE WORDS "In the preferred embodiment,.." AND ENDING WITH THE WORDS "..more slowly than the silicon." PLEASE AMEND THE SPECIFICATION WITH THE REPLACEMENT PARAGRAPH AS FOLLOWS:

In the preferred embodiment, a layer of a lithographic photoresist is first applied to one surface of the silicon substrate wafer (the surface opposite the metal layer) such that the layer is about 2 microns thick. Any technique for applying such a resist layer may be used, including dipping, spraying, spinning or vapor depositing. Either organic or inorganic resists may be used. The method of application and the composition of the resist is not critical except for the need to provide a coating layer that can be completely (or nearly so) penetrated by the light source used. Furthermore, because the resist layer must act as ~~a~~an etch barrier to the reactive plasma used subsequently to anisotropically etch exposed portions of the silicon surface, the chosen composition once cured must be eroded by the plasma considerably more slowly than the silicon.

IN THE PARAGRAPH BEGINNING AT LINE 16 WITH THE WORDS "After the resist layer is

applied.." AND ENDING WITH THE WORDS "..to satisfy this requirement." PLEASE AMEND THE SPECIFICATION WITH THE REPLACEMENT PARAGRAPH AS FOLLOWS:

After the resist layer is applied, it is hard-baked, or otherwise cured, and the desired image pattern (the mold geometry) is rendered onto the resist layer surface by using any conventional lithographic process[[,]]. ~~such~~ These processes may include using a direct contact transmission mask, a non-contact reflecting mask ([[ ]]and appropriate camera optics), ~~a~~or by using a direct "writing" technique, wherein the image is rendered by multiple passes of a programmable e-beam gun source. Important to the proper operation of the invention, however, is the ability of the exposing "light" to penetrate the full depth of the resist. Being able to fully penetrate the resist layer allows the practitioner to achieve the desired very small lateral dimensions. Use of a thin resist layer and a broadband light source ~~helps~~ help to satisfy this requirement.

IN THE PARAGRAPH BEGINNING AT LINE 26 WITH THE WORDS "After rendering the mask image.." AND ENDING WITH THE WORDS "..specific resist chemistry used." PLEASE AMEND THE SPECIFICATION WITH THE REPLACEMENT PARAGRAPH AS FOLLOWS:

After rendering the mask image into the resist, the resist layer is chemically "developed" and the exposed areas of the resist are either removed or retained, depending upon the specific resist chemistry used.

IN PAGE 7

IN THE PARAGRAPH BEGINNING AT LINE 13 WITH THE WORDS "In the preferred embodiment,.." AND ENDING WITH THE WORDS "..more slowly than the silicon." PLEASE AMEND THE SPECIFICATION WITH THE REPLACEMENT PARAGRAPH AS FOLLOWS:

Since the resist coating acts as an etchant barrier during subsequent processing, the amount of protection required will be determined by the processing necessary to provide the desired structure depth. Different combinations of resist compounds provide additional options. In the present case, a thin polymer resist is placed directly

onto a silicon substrate, hard cured, masked and exposed to a source of broadband light. The resist used in the present invention provides for about a 50-to-1 ~~processing protection~~ processing protection ratio, meaning that every micron of applied resist will protect the covered areas of the silicon wafer from attack by the reactive plasma etchant for about as long as it will take the etchant to produce a 50 microns deep trench in the wafer. The resist used, therefore, provides a sufficiently robust etchant barrier to allow etching deep, narrow, channel structures in the silicon substrate. (This, of course, implies that the silicon substrate must be thinned to ≤100 microns across the portion of the substrate intended for mold processing if a photoresist layer of 2 microns is used.)

IN PAGE 9

IN THE PARAGRAPH BEGINNING AT LINE 3 WITH THE WORDS "Referring to FIG. **1A**,.." AND ENDING WITH THE WORDS "..thick wafer." PLEASE AMEND THE SPECIFICATION WITH THE REPLACEMENT PARAGRAPH AS FOLLOWS:

Referring to FIG. **1A**, the process begins with a silicon substrate or wafer **10**. This substrate can, generally, ~~having~~ have any useful shape and thickness but should of necessity be a thin wafer having parallel top and bottom surfaces **11** and **12**, respectively. In particular, the present invention is most easily implemented by using an industry standard 100 mm ∅ x 0.67 mm thick wafer.

IN THE PARAGRAPH BEGINNING AT LINE 10 WITH THE WORDS "Surface **12** of the clean substrate.." AND ENDING WITH THE WORDS "..or alloys thereof." PLEASE AMEND THE SPECIFICATION WITH THE REPLACEMENT PARAGRAPH AS FOLLOWS:

Surface **12** of the clean substrate is coated with a metal layer **13** ~~is applied~~, comprising about 0.01 microns to about 0.1 microns of vapor deposited chromium followed by about 0.03 microns to about 0.3 microns of vapor deposited gold to provide an adherent, conductive "metallize" layer. This initial layer is followed by a second thicker layer **14** of about 25 – 50 microns of gold. Thick metal layer **14** is deposited onto layer **13** by any method known to the art for applying such coatings including but not limited to electroplating, electroless deposition, vapor or particle deposition, or chemical

vapor deposition. Metal layer **14** forms a mechanically robust "backing" layer that will eventually provide a plating surface for filling the silicon micro-mold. While layer **14** is disclosed herein as gold, it can be any of several of the oxidation resistant noble metals listed in New IUPAC Groups 9, 10 and 11 of the Periodic Table of Elements, or alloys thereof.

IN PAGE 10

IN THE PARAGRAPH BEGINNING AT LINE 1 WITH THE WORDS "In order to render.." AND ENDING WITH THE WORDS "..at a wavelength of 365nm." PLEASE AMEND THE SPECIFICATION WITH THE REPLACEMENT PARAGRAPH AS FOLLOWS:

In order to render ~~a~~an image of the desired micro-component into the resist layer **15**, a standard direct-contact lithographic mask **16** (herein embodying a positive trace image of the desired mold pattern), is placed directly on the top surface of the ~~of the~~ resist, as shown in FIG. **1C** (mask **16** is herein shown above the surface of the resist layer for clarity only). As shown in FIG. **1D**, areas **17** of resist layer **15** located beneath open areas of mask **16**, are subjected to a source of broadband light**[[,]]** that renders them sensitive to chemical development. The exposure source (not shown) used herein is a high pressure mercury-vapor lamp emitting light over a spectral range of about 365nm to 450nm and providing a dose of approximately 80 millijoules/cm^2 measured at a wavelength of 365nm.

IN THE PARAGRAPH BEGINNING AT LINE 11 WITH THE WORDS "FIG. **1E** illustrates the next step.." AND ENDING WITH THE WORDS "..material employed." PLEASE AMEND THE SPECIFICATION WITH THE REPLACEMENT PARAGRAPH AS FOLLOWS:

FIG. **1E** illustrates the next step in the process, wherein the exposed portions **17**, of photoresist layer **15**, are chemically "developed" and removed leaving only unexposed portions **19**, of layer **15** in an inverse image of the mask pattern surrounding "clear" areas **18** of exposed silicon. Again, the development step is performed using standard**[[,]]** and well-known lithographic processes associated with the particular resist material employed.

IN THE PARAGRAPH BEGINNING AT LINE 17 WITH THE WORDS "It should be noted.." AND ENDING WITH THE WORDS "..preferred than the other." PLEASE AMEND THE SPECIFICATION WITH THE REPLACEMENT PARAGRAPH AS FOLLOWS:

It should be noted that the choice of a positive or negative image mask depends largely on the nature of the photoresist used, i.e., depending upon whether or not the exposed portion of the photoresist is removed or left intact after the resist has been developed. Either approach is possible[[,]]; although, depending on the nature of the desired pattern, one is usually more preferred than the other.

IN THE PARAGRAPH BEGINNING AT LINE 10 WITH THE WORDS "After cleaning and drying,.." AND ENDING WITH THE WORDS "..chromium layer **13** is exposed." PLEASE AMEND THE SPECIFICATION WITH THE REPLACEMENT PARAGRAPH AS FOLLOWS:

After cleaning and drying, the patterned substrate **10** is subjected to an anisotropic reactive plasma etching process (not shown), such as the so-called BOSCH process described in U.S. Patent Serial number *5,501,893*, or any other similar etch-and-coat technique, wherein the exposed or "clear" areas **18** of the silicon substrate **10** are ~~etch~~etched to a depth equal to the thickness of wafer **10** (or equal to the "thinned" portion of wafer **10**) to provide a plurality of etched channels (also referred to herein as "trenches") **21**, as shown in FIG. **1F**. This step is capable of providing very high aspect ratio etched pattern such as ~~are~~ is shown in FIG. **1F**. As noted above, the BOSCH process is a ~~two-step~~two-step, etch-and-coat process wherein the intervening coating step comprises coating the exposed silicon with a thin layer of a polymer film that protects the walls and edges of the etched channel but is quickly destroyed on those surfaces which directly face the bombardment of the reactive plasma. This action has the effect of etching channels in the exposed silicon having a substantially uniform width and substantially parallel walls. The plasma etching process continues until the polymer film is consumed at which point it is stopped and a new layer of polymer film applied. The process repeats in this manner until the desired etch depth has been achieved. In the case of the present embodiment, the desired depth is substantially the full thickness of the silicon wafer wherein the chromium layer **13** is exposed.

IN PAGE 11

IN THE PARAGRAPH BEGINNING AT LINE 25 WITH THE WORDS "FIG. **2C** shows the formation ..." AND ENDING WITH THE WORDS "...Period Table of elements." PLEASE AMEND THE SPECIFICATION WITH THE REPLACEMENT PARAGRAPH AS FOLLOWS:

FIG. **2C** shows the formation of the metal micro-component in the silicon micro-mold. A final thick metal layer **25** is deposited into trenches **21** ~~form~~, thereby forming the desired part. In the present invention, layer **25** is nickel but ,as before, the material may be any similar metal or combination of metals or alloys including most of the metals in the Transition series of metal listed in New IUPAC Group Numbers 4 – 11 of the Period Table of elements.

IN PAGE 12

IN THE PARAGRAPH BEGINNING AT LINE 3 WITH THE WORDS "Following the step of depositing ..." AND ENDING WITH THE WORDS "...metal mold assembly **29**." PLEASE AMEND THE SPECIFICATION WITH THE REPLACEMENT PARAGRAPH AS FOLLOWS:

Following the step of depositing the thick layer **25**, the filled silicon micro-mold **29** is planarized, as shown in FIG. **2D**, to remove metal from across the top and bottom surfaces of filled mold **29**, thereby providing planarized surfaces **26** and **27**. Planarizing is typically performed by lapping the top surface until the surface of the silicon is reached leaving only the embedded metal pattern **28** exposed. Planarized surfaces **26** and **27** are also intended to provide a flat**[[ ]]**, smooth, and well defined top and bottom surfaces for the metal mold assembly **29**.

IN PAGE 16

IN LINE 1 BEGINNING WITH THE WORDS "The present invention describes ..." AND ENDING WITH THE WORDS "...by chemical etching." PLEASE AMEND THE SPECIFICATION WITH THE REPLACEMENT PARAGRAPH AS FOLLOWS:

The present invention describes a method for ~~fabricating an x-ray mask tool which can achieve pattern features having lateral dimension of less than 1 micron~~

rapidly fabricating a robust 3-dimensional silicon micro-mold for use in preparing complex metal micro-components. The process begins by depositing a conductive metal layer onto one surface of a silicon wafer. A thin photoresist and a standard lithographic mask are then used to transfer ~~an~~ a trace image pattern onto the opposite surface of the wafer by exposing and developing the resist. The exposed portion of the silicon substrate is anisotropically etched through the wafer thickness down to conductive metal layer to provide an etched pattern consisting of a series of rectilinear channels and recesses in the silicon which serve as the silicon micro-mold. Microcomponents are prepared with this mold by first filling the mold channels and recesses with a metal deposit, typically by electroplating, and then removing the silicon micro-mold by chemical etching.